

Networks, smart grids: new model for synchronization

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Networks of individual oscillating nodes often spontaneously synchronize and begin to oscillate at a coherent frequency. From heart cells to flashing fireflies to electric power grids, coupled oscillator networks are common in the natural world, but the conditions that allow these systems to synchronize are not well understood. The exact threshold from incoherence to synchrony is unknown. A Los Alamos scientist and collaborators developed a surprisingly simple mathematical model that accurately predicts synchronization as a function of the parameters and the topology of the underlying network.

Significance of the research

The team proposed a unique, concise, mathematical model for synchronization of dynamic networks. This model has many benefits including the following:

- Significantly improves upon the existing models advocated
- Is provably exact for various interesting network topologies and parameters
- Is statistically correct for almost all networks
- Applies to synchronization phenomena in physics, biology and engineered oscillator networks

The researchers envision that their method could be applied to assess synchronization and robustness quickly in electrical grids under volatile operating conditions.

Research achievements

The scientists illustrated the validity, accuracy and practical applicability of their model in complex network scenarios and in smart grid applications. “Smart grid” refers to technology to modernize utility electricity delivery systems, using computer-based remote control, sensing and automation.

The researchers used 10 IEEE power network test cases to examine the correctness and the predictive power of their synchronization model. IEEE had designed the large-scale electrical grid network test cases as benchmark models for power flow and stability studies. Under nominal operating conditions in electrical grids, the power generation is optimized to meet the forecast demand while obeying the AC power flow laws and respecting the thermal limits of each transmission line.

The researchers validated the synchronization condition in a volatile smart grid scenario that included fluctuating loads with random power demand, renewable energy sources with severely fluctuating power outputs and fast-ramping generation and controllable loads. In this test case, a series of events, caused by the loss of a generator and increased power demand, caused a loss of synchronization and outage of a transmission line that would precipitate a blackout. The team’s calculations confirmed the validity, the applicability and the accuracy of the synchronization condition in the complex power network scenarios.

The research team

Scientists on the research team are Michael Chertkov of LANL's Physics of Condensed Matter and Complex Systems group and Florian Dörfler and Francesco Bullo of University of California, Santa Barbara. The journal *Proceedings of the National Academy of Sciences USA* published their findings. Laboratory Directed Research and Development (LDRD) funded the Los Alamos research, which supports the Lab’s Energy Security and Global Security mission areas and the Information, Science, and Technology science pillar.

Caption: Schematic of an electrical power production and distribution system. Credit: DOE.

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